QA4EO | A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

Facilitating Inter-operability: The data Quality Assurance strategy of CEOS to address the needs of GEOSS

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Changyong Cao	National Oceanic and Atmospheric Administration
Marie-Claire Greening	Greening consultants Ltd, UK

+ Cal/Val Community

Requirement

- The Group on Earth Observations (GEO)'s Global Earth Observation System of Systems (GEOSS) must deliver comprehensive "knowledge / information products" worldwide and in a timely manner to meet the needs of its nine "societal benefit areas".
- This will be achieved through the synergistic use and combination of data derived from a variety of sources (satellite, airborne and *in-situ*) through the coordinated resources and efforts of the GEO members.
- Achieving this vision requires the establishment of an operational framework to facilitate interoperability and harmonisation.

CEOS: structure and role

Established in 1984, **CEOS (Committee on Earth Observation Satellites)** is recognized as the **major international forum** for the coordination of Earth observation satellite programs and for interaction of these programs with users of satellite data worldwide. In its partnership with GEO, **CEOS has become the space-based component of GEOSS**, and the "space arm" of GEO.

CEOS
Chair: Darasri Dowreang **(Thailand, 2009)**
2008: Pontsho Maruping (South Africa), 2007: Barbara Ryan (USGS)

SIT (Strategic Implementation Team)
Chair: Mary Kicza (NOAA, 2008-2009)
Space agency principals

WGISS (Working Group on Information Systems and Services)
Chair: Martha Maiden (NASA, 2008-2010)

WGCV (Working Group on Cal/Val)
Chair: Pascal Lecomte (ESA, 2008-2010)

WGEdu (Working Group on Education)
Chair: Gordon Bridge (EUMETSAT, 2008-2010)

CEOS Members (29) and Associates (20)

CEOS Members

Organization	Headquarters Location	Year Admitted/ Chair Agency	Principal (P) Contact (C) Secretariat Rep (S)
Agenzia Spaziale Italiano (ASI)	Italy	1986	P-Mr. Augusto Cramarossa C-Mr. Alberto Tuozzi C-Mr. Bianco Giuseppe
British National Space Centre (BNSC)	UK	1986/2005	P-Dr. David Williams C-Dr. Arwyn Davies C-Mr. Mark Churchyard
Chinese Academy of Space Technology (CAST)	P. R. China	1993	P- Prof. FuXiang Xu C-Prof. WeiYuan Yang
Center for the Development of Industrial Technology (CDTI)	Spain	2007	P-Mr. Jorge Lomba C- Ms. Mónica López
Centre National d'Etudes Spatiales (CNES)	France	1984	P-Dr. Pascale Ultré-Guérard C-Mr. Steven Hosford
Comision Nacional de Actividades Espaciales (CONAE)	Argentina	1999/2006	P-Dr. Conrado Varotto C-Dr. Laura Frulla S-Ms. Ana Medico
ChinaCenter for Resources Satellite Data and Application (CRESDA)	China	2007	
Canadian Space Agency (CSA)	Canada	1984	P-Dr. Savi Sachdev C-Mr. Daniel DeLisle
Commonwealth Scientific and Industrial Research Organistion (CSIRO)	Australia	1989	P,C-Dr. Alex Held
Deutsches Zentrum für Luft- und Raumfahrt (DLR)	Germany	1986	P,C- Mr. Klaus Schmidt
European Commission (EC)	Belgium	1994	P-Mr. Paul Weissenberg C-Val ére Moutarlier C-Mauro Facchini
European Space Agency (ESA)	France	1984	CEO-Mr. Ivan Petiteville P-Dr. Volker Liebig C-Dr. Evangelina Oriol-Pibernat C-Dr. Stephen Briggs C-Ms. Simonetta Cheli
European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)	Germany	1989	P-Dr. Lars Prahm C-Dr. Robert Husband C-Dr. Paul Counet
Geo-Informatics and Space Technology Development Agency (GISTDA)	Thailand	2001/2009	P-Dr. Darasri Dowreang C-Dr. Pakon Apaphant C-Ms. Poonthip Sirikulchayanon C-Ms. Kulthida Sungsiri S-Mr. Phuriwaj Rueangnaowaroj S-Ms. Chirakanya Khamdee
Instituto Nacional de Pesquisas Espaciais (INPE)	Brazil	1984	P-Dr. Julio D'Alge C-Dr. Gilberto Camara
Indian Space Research Organisation (ISRO)	India	1984	P-Dr. RR Navalgund C-Dr. VS Hegde
Japan Aerospace Exploration Agency (JAXA)	Japan	1984	P-Dr. Yasushi Horikawa C-Mr. Makoto Kajii C-Mr. Chiyoshi Kawamoto S-Ms. Satoko Miura S-Ms. Kazuko Misawa
Korea Aerospace Research Institute (KARI)	R. Korea	2001	P-Dr. Zeen-Chul Kim C-Dr. Hyo-Suk Lim
Ministry of Education, Culture, Sports, Science and Technology (MEXT)	Japan	1984	P-Mr. Masaaki Tanaka C-Mr. Ken Matsui C-Mr. Takeshi Sasada
National Aeronautics and Space Administration (NASA)	US	1984	P-Dr. Michael Freilich C-Mr. Chris Blackerby S-Mr. Stephen Sandford
National Space Research and Development Agency (NASRDA)	Nigeria	2004	P-Prof. R. A. Boroffice
National Remote Sensing Center of China (NRSCC)	P. R. China	1993/2004	P-Mr. Zhang Guocheng C-Dr. Li Jiahong
National Space Agency of Ukraine (NKAU)	Ukraine	1993	P-Dr. Eduard Kuznetzov C-Prof. Oleg Fedorov
National Oceanic and Atmospheric Administration (NOAA)	US	1994	P-Mrs. Mary Kicza C-Dr. Brent Smith C-Mrs. Kerry Sawyer S-Ms. Linda Moodie S-Judy Carrodeguas
Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET)	Russia	1992	P-Dr. Valeriy Diaduchenko C-Dr. Alexander Uspensky
Russian Aviation and Space Agency (Roskosmos)	Russia	1992	P-Prof.Gregory M. Polyshchuk C-Dr. Sergei Kulik
Space Technologies Research Institute of Turkey (Tubitak-Uzay)	Turkey	2006	P-Mr. Erol Tunali
Scientific and Research Center on Space Hydrometeorology Planeta (SRC)	Russia	1992	P-Dr. Asmus Vasily C-Dr. Elena Manaenkova
United States Geological Survey (USGS)	US	2000	P-Dr. Bryant Cramer C-Mr. Timothy Stryker S-Dr. Bruce Quirk

CEOS Associates

Organization	Headquarters Location	Year Admitted/ Chair Agency	Principal (P) Contact (C)
Belgian Science Policy Office (BELSPO), formerly OSTC	Belgium	1993	P-Mr. Peter Van Geloven
Canada Centre for Remote Sensing (CCRS)	Canada	1990	P-Mr. Stuart Salter C-Dr. Jean-Marc Chouinard
Crown Research Institute (CRI)	New Zealand	1990	P-Dr. Andy Pearce C-Ms. Stella Belliss
Satellite Applications Centre (SAC) / South African Council for Scientific and Industrial Research (CSIR)	South Africa	1998/2008	P-Mr. Wabile Motswasele C-Ms. Asanda Ntisana C-Mr. Alex Fortescue S-Mr. Daniel Matsapola
United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)	Thailand	1996	P-Mr. Guoxiang Wu C-Mr. Cengiz Ertuna
United Nations Food and Agriculture Organization (FAO)	Italy	1993	P-Mr. Jeff Tschirley C-Mr. Jelle U. Hielkema
Global Climate Observing System (GCOS)	Switzerland	1992	P-Prof. Paul Mason C-Dr. Stephan Bojinkski
Global Ocean Observing System (GOOS)	France	1992	P-Dr. Keith Alverson
International Council of Scientific Unions (ICSU)	France	1991	Dr. Gisbert Glaser Dr. Deliang Chen Ms. Rohini Rao
International Geosphere-Biosphere Program (IGBP)	Sweden	1991	P-Dr. Carlos Nobre C-Prof. Kevin Noone
Intergovernmental Oceanographic Commission (IOC)	France	1991	P-Dr. Keith Alverson
International Ocean Colour Coordinating Group (IOCCG)	Nova Scotia	1999	C- Prof. James Yoder C- Dr. Venetia Stuart
International Society for Photogrammetry and Remote Sensing (ISPRS)	UK	1997	P-Prof. Ian Dowman
Norwegian Space Center (NSC)	Norway	1990	P-Mr. Bo Andersen C-Mr. Per Erik Skrovseth
Swedish National Space Board (SNSB)	Sweden	1991	P-Per Tegner C-Mr. Goran Boberg
United Nations Environment Program (UNEP)	Kenya	1992	P-Dr. Peter Gilruth C-Dr. Fernandez Norberto
United Nations Educational, Scientific and Cultural Organization (UNESCO)	France	2003	P-Mr. Walter Erdelen C-Mr. Robert Missotten C-Mr. Guoxiang Wu
United Nations Office for Outer Space Affairs (UNOOSA)	Austria	1994	P-Dr. Mazlan Othman C-Dr. Hans Haubold
World Climate Research Program (WCRP)	Switzerland	1991	P-Dr. Ghassem Asrar
World Meteorological Organization (WMO)	Switzerland	1991	P-Mr. Jerome Lafeuille C-Dr. Barbara Ryan

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CEOS Working Group on Cal/Val (WGCV)

- **WGCV**
  - Chair: Mr. P. Lecomte, ESA
  - Vice Chair: Mr. G. Stensaas, USGS
  - Technical Secretariat: Dr. M. Greening, Greening Consulting

- **WGCV Subgroups**
  - Synthetic Aperture Radar (SAR)
    Chair: Dr. S. Srivastava, CSA
  - Infrared Visible Optical Sensors (IVOS)
    Chair: Dr. N. Fox, NPL
  - Microwave Sensors (MWS)
    Chairs: Dr. C. Buck, ESA *and* Dr. X. Dong, CSSAR
  - Terrain Mapping (TMSG)
    Chair: Prof. J. P. Muller, UCL
  - Land Product Validation (LPV)
    Chair: Dr. F. Baret, INRA
    Vice Chair: Dr. S. Garrigues, CNES
  - Atmospheric Chemistry (ACSG)
    Chair: Dr. B. Bojkov, ESA
    Vice Chair: Dr. J-C. Lambert, IASB/BIRA

GEO task: DA-06-02 evolved into DA-09-01a

"The success of GEOSS will depend on data and information providers accepting and implementing a set of interoperability arrangements, including technical specifications for collecting, processing, storing, and disseminating shared data, metadata, and products". (from the GEOSS 10 yr. Implementation plan)

Interoperability implies **Data Quality Assurance** since:

Data accessible ≠ Data usable

"Without a performance (quality) indicator a result has no meaning"

GEO Task DA-06-02: "Develop a GEO data quality assurance strategy, beginning with space-based observations and evaluating expansion to in-situ observations, taking account of existing work in this area".

Led by: CEOS and IEEE

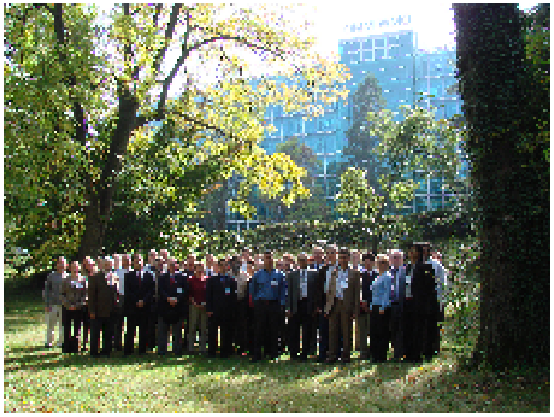
n.b ***not necessarily high accuracy/best quality but quantified to allow easy assessment of its "fitness for purpose"***

QA4EO A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

Strategy development: community engagement

Strategy development led by small CEOS team through two community workshops, CEOS sub-groups and ad-hoc meetings

"GEO/CEOS workshop on quality assurance of calibration and validation processes:



guiding principles"
(*Geneva Oct 07*)

Establishing an operational framework"
(*Washington May 08*)

Peer review completed Sep 08

CEOS approval with incorporated changes Nov 08

Operational framework: Principles

GEOSS: Seamless & continuous delivery of information products to meet needs of societal benefit areas

Interoperability arrangements to allow combinations of disparate sources of data

Data Quality

Accessibility Availability

Suitability Reliability

Fit For purpose

Strategy:
Establish set of guidelines based on "best practices" to be endorsed by CEOS, under auspices of GEO and implemented by the agencies

All data and derived products must have associated with them a **Quality Indicator** based on a documented quantitative assessment of its **traceability** to an agreed reference standard (ideally tied to SI).

Comparisons

Procedures

Reference standards (with method of use): including designation of "test sites"

This framework, in the context of data and derived products, is dependent on the successful implementation of two principles:

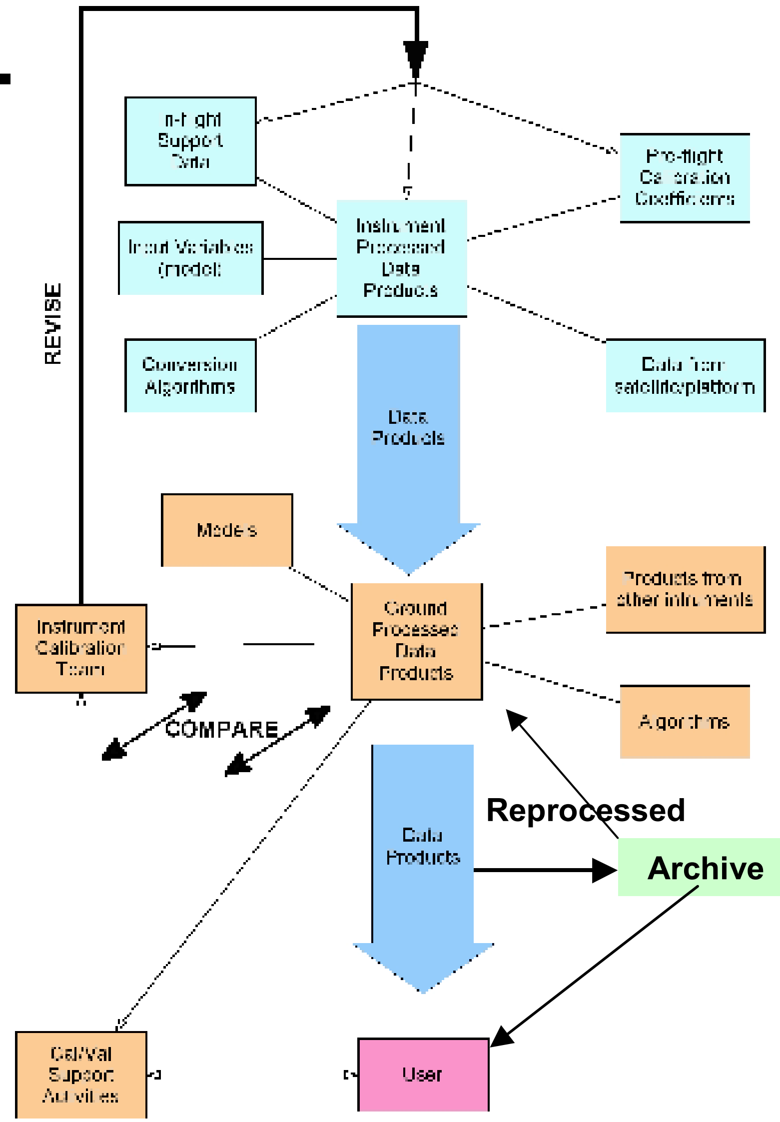
- **Accessibility / Availability**
- **Suitability / Reliability**

And the means to efficiently communicate these attributes to all stakeholders.

Operational framework: scope

Its scope encompasses the whole EO sector:

- **All sensor types & operational domains**
- **Data collection**
- **Processing (Level 1 to Level n)**
- **Distribution**



Operational framework: Structure

To enable these principles to be implemented in a harmonised manner, the Committee on Earth Observation Satellites (CEOS), the space arm of GEOSS, following discussion at two international workshops of Cal/Val experts, has established a quality assurance (QA) framework.

This framework consists of a set of operational guidelines derived from "best practices" for implementation by the community. These guidelines have been collated into three theme areas:

- **Data Quality**,
- **Data Policy** *and*
- **Communication & Education**

Each theme has an overarching "guiding principle" towards achieving interoperability with a minimal set of "key guidelines" to aid harmonisation.

Data Quality

All data and derived products must have associated with them a ***Quality Indicator (QI)*** *based on documented quantitative assessment of its traceability to community agreed reference standards. This requires all steps in the data and product delivery chain (collection, archiving, processing and dissemination) to be documented with evidence of their* ***traceability.***

Traceability: *property of a measurement result relating the result to a stated* ***metrological reference*** *through an* ***unbroken*** *chain of calibrations of a measuring system or comparisons, each contributing to the stated measurement* ***uncertainty***
(ISO guide 99:2007)

- **Guidelines are generic in scope to cover all data-related "activities".**
- **Provide guidance (and indicative templates) on how to establish a QI and means to obtain and document associated evidence.**

- **Content / writing of a "procedure"**
- **Validating models & Algorithms**
- **Selecting "Reference standards"**
- **Evaluating Uncertainties**
- **Organising and analysing comparisons**
- **Evidence of traceability**

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Data Policy

The data must be freely and readily available / accessible / useable in an unencumbered manner for the good of the GEOSS community, for both current and future users. This necessitates that all Cal/Val data and associated support information (metadata, processing methodologies, Quality Assurance, etc.) is associated with the means to effectively implement a Quality Indicator. In return, the data provider must be consistently acknowledged.

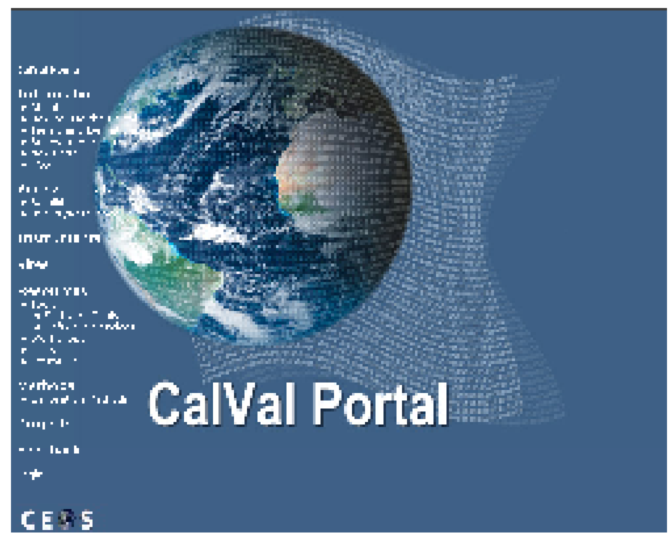
Guidelines are based on the adoption of existing "best" and commonly-used practises

- **Common metadata content and its linkage with datasets**
- **Domain harmonised formats for Cal/Val data exchange**
- **"Code of practise" for Cal/Val data providers & users**

Communication and Education

Interoperability requires all stakeholders to have a clear understanding of the adequacy of the information that they are accessing and using for their specific application, i.e. its "fitness for purpose". The evidence for this clarity will be accessible through a single portal (http://calvalportal.ceos.org) and will be fully traceable to its origins. The traceability and interoperability process must be understandable by any appropriately trained individual throughout GEOSS and efforts must be made to encourage the wider usage of information and facilitate the training of GEOSS users.

- **Dictionary of terminology**
- **Maintenance / evolution & utilisation of a Cal/Val Portal for all EO sensor domains**
- **Document management system**
- **Facilitate education and capacity building to promote use of QA4EO**



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Data Quality: Implementation

- Following the key guidelines within QA4EO should allow all stakeholders to have confidence in any assigned Quality Indicator (QI).
- Where appropriate, sensor- or application- specific guidelines/procedures may be endorsed by CEOS on behalf of the community to facilitate harmonisation.
  - The structure / content of these additional guidelines should follow that of the Key guidelines
  - Ideally based on agreed "mature" best practise
  - Are not necessarily unique
  - "peer review" and endorsement through CEOS WGCV sub-groups
- Individual agencies will be responsible for implementation in their "domain of influence" although CEOS WGCV will provide technical support and a forum for ensuring inter-agency consistency.
- The key requirement is "documented evidence and quantification of traceability to an agreed reference"
- Evolution of guidelines as a result of feedback and to encompass full GEOSS community

Data Quality Guidelines

Available at: **http://wgcv.ceos.org/index.html**

or at the CEOS Cal/Val Portal **>>>>>** ***http://calvalportal.ceos.org***

QA4EO-CEOS-GEN-DQK-001

A guide to establishing a Quality Indicator on a satellite sensor derived data product

Translation of "Guiding principle" which underpins the philosophy of QA4EO data quality

QA4EO-CEOS-GEN-DQK-002

A guide to content of a documentary procedure to meet the Quality Assurance (QA) requirements of CEOS

Procedural template / "checklist" to aid the harmonised collection and presentation of data to achieve the requirements of ….DQK-001

Data Quality Guidelines

Specific Guidance on key elements of data QA process

QA4EO-CEOS-GEN-DQK-003

A guide to "reference standards" in support of Quality Assurance requirements of QA4EO

QA4EO-CEOS-GEN-DQK-004

A guide to comparisons – organisation, operation and analysis to establish measurement equivalence to underpin the Quality Assurance requirements of QA4EO

QA4EO-CEOS-GEN-DQK-005

A guide to establishing validated models, algorithms and software to underpin the Quality Assurance requirements of QA4EO

QA4EO-CEOS-GEN-DQK-006

A guide to expression of uncertainty of measurements

QA4EO-CEOS-GEN-DQK-007

A guide to establishing quantitative evidence of traceability to underpin the Quality Assurance requirements of QA4EO

Data Quality Guidelines

Specific Guidance on key elements of data policy and education

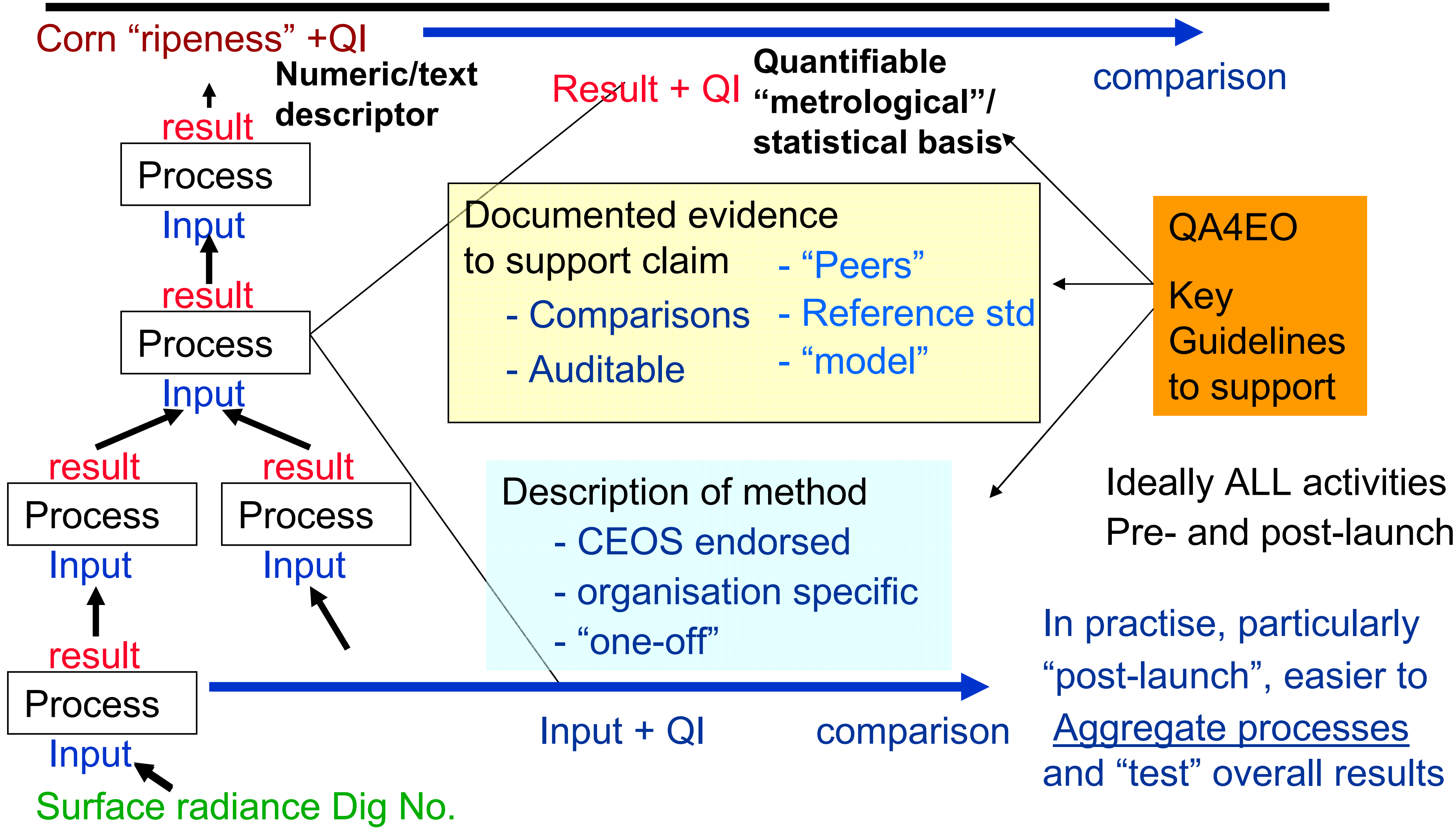
[QA4EO-CEOS-GEN-DPK-001]
A guide to Cal/Val data sharing principles and data exchange

[QA4EO-CEOS-GEN-DPK-002]
A guide to the provision of Cal/Val data content and metadata

[QA4EO-CEOS-GEN-CEK-001]
A guide to procedure and document management

Established Specific Guideline
QA4EO-WGCV-IVO-CLP-001
Use of the Moon for in-flight calibration stability monitoring

QA4EO data quality guidelines



GdIn …DQK 001 Example: LSI radiometric gain

All data products must have associated with them a Quality Indicator (QI) based on documented quantitative assessment of its traceability to an agreed reference standard (ideally tied to SI).

Follow guidance:
QA4EO-CEOS-GEN_DQK-002

To establish a QI for a satellite sensor derived data product requires knowledge of sensor performance and this can be best evaluated through the following guidelines: (QA4EO-CEOS-DQK-001)

Pre-Flight

- Traceably calibrate all sub-systems
- Perform "end to end" system calibration
- Maintain witness samples of key components for later testing as necessary.

Post Launch:

Evaluate sensor performance for the following aspects:

- "Characteristics" compared to pre-flight
- Biases to other in-flight sensors.
- "Stability" of products (in mission, & link to history and future).

Can be best achieved through comparison to "CEOS Standard" using a "CEOS method".

e.g. LAND imager constellation

Characteristics e.g. "Gain"

- On board standard
- CEOS core test site
- Rayleigh scattering
- Clouds
- Moon
-

Bias

- SNO
- CEOS core test site
- CEOS invariant standard

Stability

- CEOS invariant standard ("standard desserts", moon)
- CEOS core test site
- On-board standard

Example: Post-launch Cal/Val "reference stds"

Role and characteristics

•Establish confidence in / correct pre-launch sensor characteristics & products

Independent Knowledge of characteristics of reference with uncertainty

- Evaluate Consistency / biases with similar "in-flight sensors"

Temporal stability and "commonality of observable" between sensor A & B views

- Maintain in-flight characteristics, long-term continuity and bridge potential "data gaps"

Long-term stability or ability to re-characterise consistently

Challenges: Atmosphere, variability of natural sites, characterisation & maintenance, geographical distribution,

Optimum solution: Flight of a "benchmark" mission with demonstrably high accuracy and inherent traceability e.g. **TRUTHS / CLARREO** can then also regularly re-calibrate reference standards

CEOS pursuing all options (complementary to each other).

- Is now establishing "reference stds" and associated "operational procedures" for use by agencies

CEOS WGCV:IVOS “instrumented sites” (LandNet)

Reference stds for radiometric gain (land imagers) Ideally Need Ten!

- Standardised procedures to aid characterisation (and for new sites)
- Comparisons of “field measurement” techniques to ensure consistency

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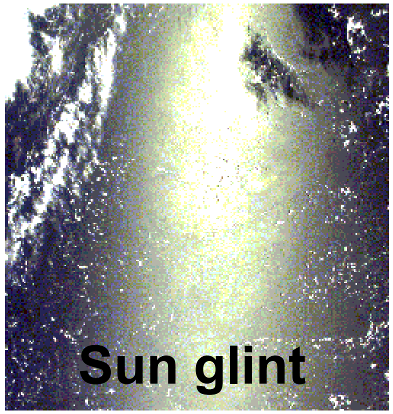
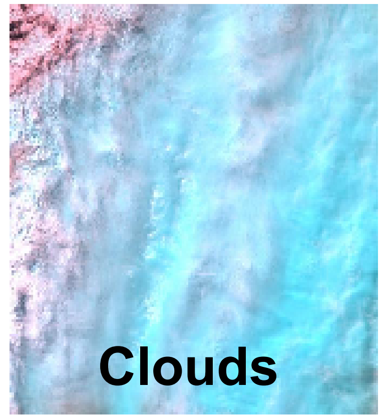
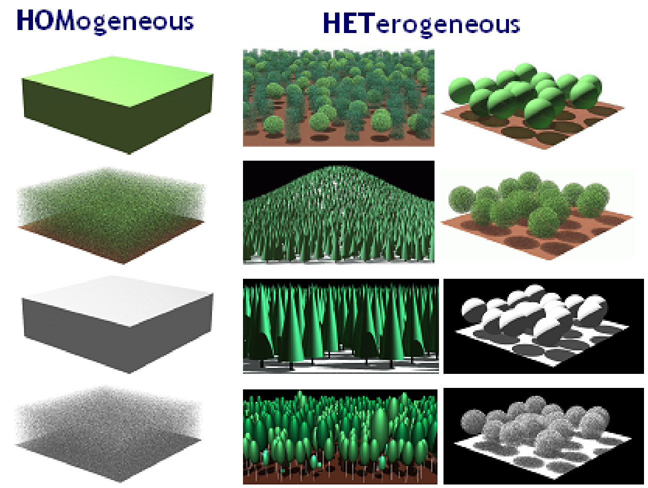
CEOS WGCV IVOS: “stability” Reference standards

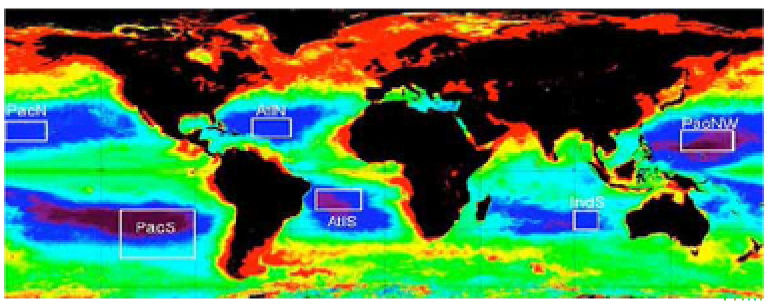
"intrinsic standards" (methods) & transient stds







Radiation Transfer model intercomparison (RAMI) of JRC



Rayleigh Calibration Sites – Choice of oligotrophic areas with 2 years of SeaWiFS data made in 2001 with ACRI and LOV (CLIMZOO zones)

Ocean buoys & ships

"test data sets" to evaluate models, algorithms and software

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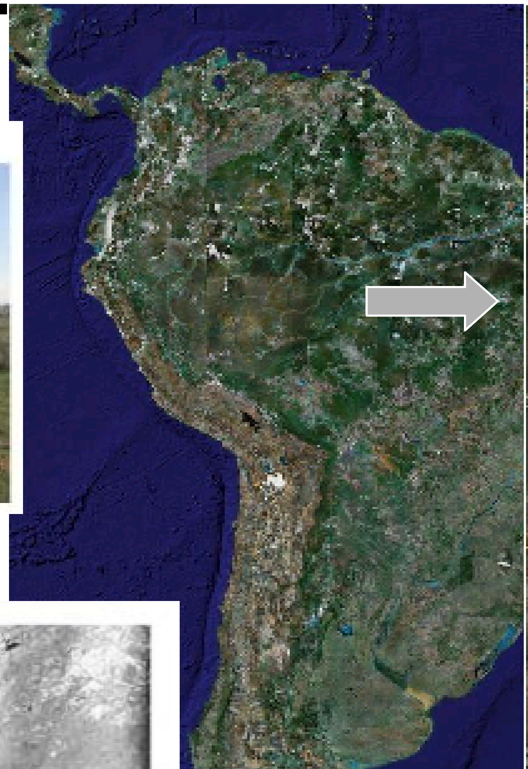
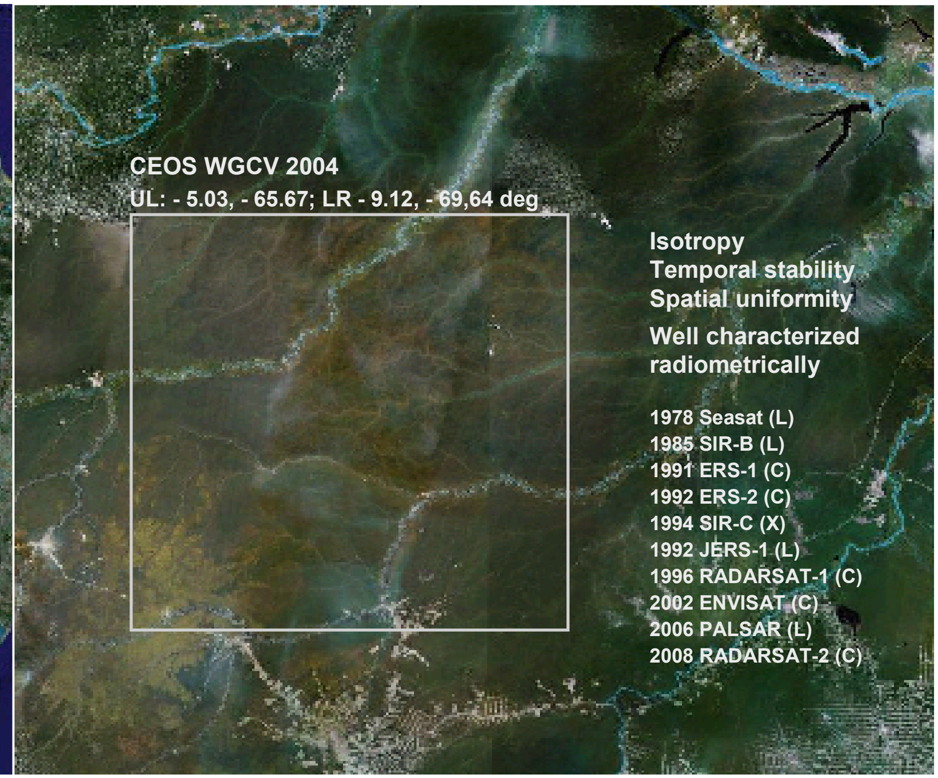
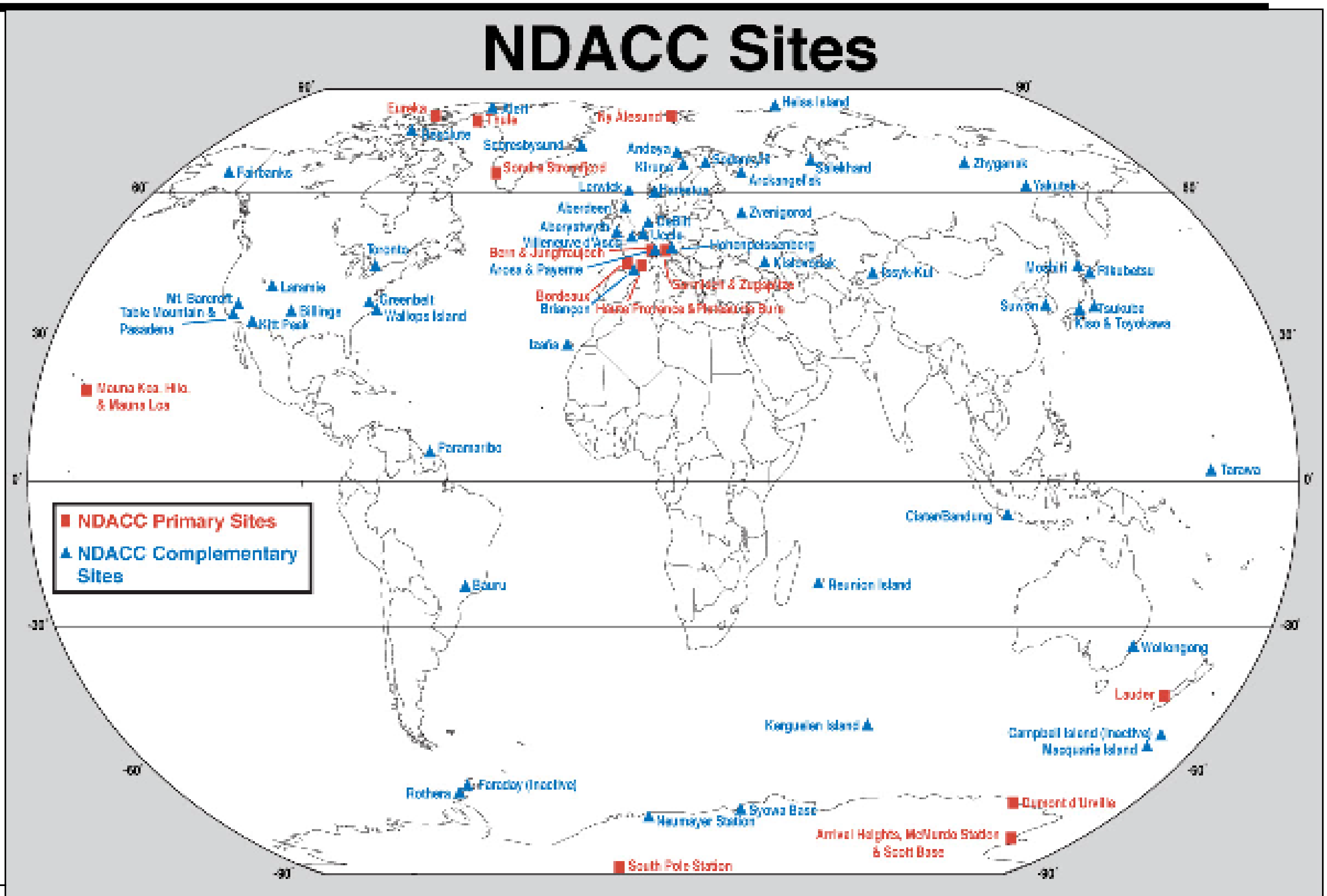
Reference standards for SAR imagers





Combinations of Natural and man-made standards

Atmospheric composition: Reference standard sites (core instruments and procedures)



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Methodologies and support instrumentation

Validation of sea-surface temperature utilises IR radiometers, must be traceable to SI and intercompared. Next comparison April 2009

CEOS references std sites must be characterised consistently, with instrumentation calibrated traceable to SI. International comparison planned for 2010

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Implementation

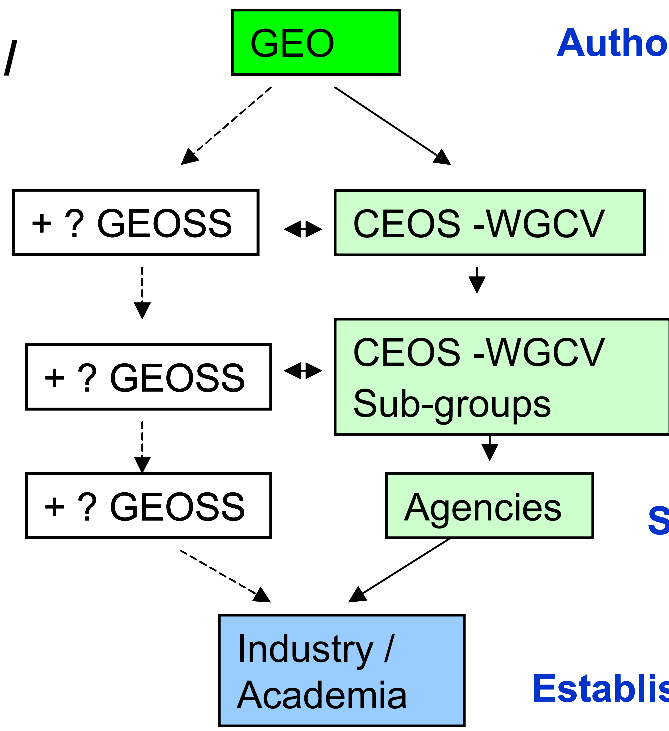
TOP DOWN

(operational framework / "key guidelines")

Harmonisation

Interoperability

"Operational GEOSS"



Authorising body

Process management / "standardising body" International coordination

Technical management "peer review" "best-practises"

Specify / Review/ Approve

Establish and Document evidence

BOTTOM UP

(technical procedures / "best practises")

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Task DA-09-01a current actions

- DA-09-01a_5 - Benchmark mission coordination: Benchmark mission coordination between TRUTHS and CLARREO missions
- DA-09-01a _6 - Ground based cal/val campaign
- DA-09-01a_7 - Complete DOME-C Multi-Sensor Experiment
- DA-09-01a_8 - Cal/Val Portal and post-launch Test Sites (reference standards)
- DA-09-01a_9 - Develop radiometric standards for use in Earth Observation and develop a handbook.
- DA-09-01a_10 - Quality Assurance Framework for Earth Observation (QA4EO) Implementation
- DA-09-01a_11 - Reference Test Site Data Collaboration and Comparison

Summary

- QA4EO provides a practical means to facilitate harmonisation and the robust assignment of a Quality Indicator to data and derived products.

- The key guidelines have been established by CEOS with active participation of the worlds (space related) Cal/Val community subsequent procedures and "best practises" are now being written by the community.

- CEOS recommended GEO adoption and implementation throughout the world

- QA4EO will be evolved as necessary to take account of any additional specific requirements of the wider GEOSS community.

- Successful implementation will provide major benefit to all stakeholders and allow the dream of GEOSS to be an achievable target.

- International coordination in the development and maintenance of the necessary infrastructure and associated support activities including training (independent of specific missions) will be essential for success.

Back up Slides

GdIn …..DQK-004: Comparisons

- **Suggests this as primary means of establishing evidence of performance and traceability**
  - To an artefact
  - Against peers
    - **Key comparisons** – Few defined by CEOS to test key principles
    - **Supplementary comparisons** – defined by anyone to test specifics as needed
- **Provides pro-forma for organisation, analysis and reporting based on that used by Nat stds labs**
  - Must be "blind"
  - Must have uncertainties
  - Participants opportunity to review peers before seeing results
  - Must be published (no withdrawals) but can be repeated
  - Encouragement of open and inclusive participation
- **CEOS WGCV and sub-groups to provide a framework for approval of results.**
- **Provides an example "protocol" and analysis**

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GdIn …..DQK-005 and 006: Uncertainties and models, algorithms and software

- QA4EO guidelines serve as a pointer to other existing guidelines.
- Both provide a brief outline summary of the content of the existing guidelines.
- Need EO targeted case studies and training to aid community understanding particularly in gdl 6 (highlighted in peer review)

GdIn …..DQK-007: "Establishing evidence"

- Provides a summary of the overall requirement
- Proposes that comparisons are "key" but can be used in "sampling" mode and test aggregates not everything
- Is a place holder and pointer for the community to define "satisfactory evidence"
- Provides a framework to encourage how this evidence will be defined, agreed and made visible to the community.
- Needs work to refine "implied linked content" and is focus for effort during implementation phase.
- Needs infrastructure to facilitate practical implementation